Status Review of the Southern Stock of Bocaccio (*Sebastes paucispinis*)

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Appendix 1: 2002 Bocaccio Stock Assessment
Appendix 2: 2002 Bocaccio rebuilding Analysis

EXECUTIVE SUMMARY

This status review was conducted in response to a petition to list bocaccio under the Endangered Species Act (Natural Resources Defense Council, Center for Biological Diversity and Center for Marine Conservation to NMFS Office of Protected Resources, January 25, 2001, "A petition to list the central/southern population of bocaccio (*Sebastes paucispinis*) as a threatened species").

In determining whether a listing under the ESA is warranted, two key questions must be addressed: 1) " Is the entity in question a "species" as defined by the ESA?" and 2) If so, "Is the "species" threatened or endangered?" With regard to the first question, the ESA allows listing of "distinct population segments" (DPSs) of vertebrates as well as named species and subspecies. The bocaccio off California show genetic differences (ca. 90% probability) from the bocaccio off Washington. Accordingly, the bocaccio population off Mexico (about 10% of the total abundance) and California, is treated as a DPS for the purposes of ESA consideration.

Bocaccio are moderately long-lived, with maximum observed ages of 30 to 40 years. They take about five years to mature, and have a mean generation time of 12 years in the absence of fishing. Bocaccio recruitment (addition of young fish to the population) is highly variable, with successful reproduction (where production of offspring offsets natural loss of adults) has occurred in only 26% of years. A few historical recruitments have been very large, but no large recruitment events have occurred since 1978. Because of this pattern of highly variable recruitment, abundance fluctuates naturally, having ranged between 26% and 95% of estimated average unfished reproductive potential in the period 1951 to 1970. Under the influence of intense fishing and poor recruitment, abundance declined steadily since then, reaching 3.6% of unfished reproductive potential in 2002. Current abundance (age 1 and older) is about 3,000 metric tons, and is 1.6 million fish.

Historical overfishing was based on an assumption that the bocaccio stock had a productivity typical of other worldwide fish stocks. Experience has now shown that productivity is unusually low. The federal laws governing fishery management have been strengthened with regard to overfishing, and bocaccio is now under rebuilding, as required by the reauthorized Magnuson-Stevens Fishery Management and Conservation Act. Allowable catch rates (catch/total biomass) under rebuilding are very low (approximately 0.5% in 2003, compared with an average rate of 11% during the preceding 50 years). Rebuilding is expected to take approximately 170 years. A Population Viability Analysis shows that the stock has a low probability of declining severely in the next 25 to 100 years if the rebuilding catch rates are observed.

INTRODUCTION

Bocaccio (*Sebastes paucispinis*) is a common rockfish occurring in coastal waters of the northeastern Pacific from Mexico to Alaska (Miller and Lea 1972). Historically, bocaccio sustained the greatest harvest of any rockfish species in California waters, but according to the most recent stock assessment (MacCall 2002, included as Appendix 1 to this document) the stock has declined to a relatively low level of abundance in recent years.

Rockfish in general have a life history that is susceptible to overharvesting: they are long-lived, and have a relatively low compensatory capacity (low steepness) in their stock-recruitment relationships (Dorn 2002). Bocaccio is one of several rockfish stocks off California, Oregon and Washington that have been formally declared as "overfished" by the Pacific Fishery Management Council (PFMC) and the National Marine Fisheries Service (NMFS). An overfished condition exists if abundance of a west coast groundfihs stock falls below 25% of the estimated unfished or virgin abundance, in which case a rebuilding analysis is conducted and a Rebuilding Plan is implemented as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). A Rebuilding Analysis has been conducted for bocaccio (MacCall and He 2002, included as Appendix 2 to this document) and a Rebuilding Plan is in preparation by the PFMC.

Scope and Intent of the Present Document

This document is the status review in response to a petition[1] to list bocaccio under the Endangered Species Act. Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. §1533(b)(3)(A)). NMFS decided that the petition had sufficient merit for consideration and that a status review was warranted (66 Fed. Reg. 32304, June 14, 2001). The ESA stipulates that listing determinations should be made on the basis of the best scientific and commercial information available. The National Marine Fisheries Service appointed the authors of the most recent PFMC bocaccio assessment (MacCall 2002) and Rebuilding Analysis (MacCall and He 2002) to undertake a scientific review of the biology, population status and future outlook for bocaccio. This document reports this team's conclusions regarding the biological status of bocaccio as a potential candidate for listing under the ESA. These conclusions are subject to revision should important new information arise in the future.

Bocaccio abundance is low relative to the estimated unfished level, and reproductive rates have

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[1] Natural Resources Defense Council, Center for Biological Diversity and Center for Marine Conservation to NMFS Office of Protected Resources, January 25, 2001, "A petition to list the central/southern population of bocaccio (*Sebastes paucispinis*) as a threatened species"

not compensated for fishery harvests in recent years. Although bocaccio is one of the best studied and data-rich species on the U.S. west coast, some aspects of bocaccio biology remain poorly understood. The primary threat to the species is harvest, both intentional and unintentional (i.e., as bycatch). Bocaccio catches have been reduced severely by the PFMC. The 1998-2001 average annual catch (219 metric tons, mt) was 11% of the 1990-1995 average (1956 mt), and the 2002 groundfish fishery was curtailed at the beginning of July when the total bocaccio catch had reached approximately 100 mt. Further reductions in catch are planned beginning in 2003 according to the Rebuilding Plan that is in preparation. Rebuilding analyses conducted by the PFMC focus on the probability of abundance increasing to 40% of the estimated unfished level within a time frame that is not greater than the length of time needed to rebuild in the absence of fishing, plus one mean generation time (this length of time is over 100 years, details are provided elsewhere in this document). However, rebuilding analyses generally do not examine the likelihood of extinction during the course of rebuilding. It is possible that a rebuilding policy with a high probability of success may nonetheless also have a small probability of extinction; these aspects are not mutually exclusive.

Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" threatened or endangered?

These two questions are addressed in separate sections of this report. NMFS is required by law (ESA Sec. 4(a)(1)) to determine whether one or more of the following factors is/are responsible for the species' threatened or endangered status:

The present or threatened
(A) destruction, modification or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;
(C) disease or predation;
(D) inadequacy of existing regulatory mechanisms; or
(E) other natural or human factors affecting its continued existence.

The "Species" Question: In determining whether to list a species, the first issue is whether the petitioned subject is a valid species. After determining whether the petition identifies a species, the next issue is whether there are "distinct population segments" (DPSs) within the species. However, the ESA provides no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity has led to the use of a variety of approaches for considering vertebrate populations. This led the Fish and Wildlife Service and NMFS to publish a Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act (61 FR 4722). The policy identifies two elements in a decision regarding whether it is appropriate to identify separate DPSs: discreteness and significance of the population segment to the species. A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors or if it is delimited by international governmental boundaries. If a population segment is considered discrete, its biological and ecological significance will be evaluated on the basis of considerations including, but not limited to its persistence, evidence that loss of the DPS would result in a significant gap, evidence of the DPS representing the only surviving natural occurrence of a taxon, or evidence that the DPS differs markedly in its genetic characteristics. Then if the DPS is appropriate, the status of the DPS should be considered separately in relation to the standards of the ESA. A more detailed discussion of this topic appeared in the NMFS "Definition of Species" paper (Waples 1991).

The "Extinction Risk" Question: The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by an DPS in deciding whether the DPS is threatened or endangered. Important considerations include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) any trends in abundance; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., artificial rearing); and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific and commercial information available regarding its current status, after taking into consideration conservation measures that are being made. In this review, we do not evaluate likely or possible effects of conservation measures. Therefore, we do not make recommendations as to whether the species or identified DPSs should be listed as threatened or endangered species. Rather, we have drawn scientific conclusions about the risk of extinction faced by identified DPSs under the assumption that present conditions will continue (recognizing, of course, that natural demographic and environmental variability is an inherent feature of "present conditions"). Conservation measures will be taken into account by NMFS in making its listing recommendations.

Summary of the Bocaccio Listing Petition

A document titled “A petition of list the central/southern population of bocaccio (*Sebastes paucispinis*) as a threatened species” dated 1/25/01 was filed in the NMFS Office of Protected Resources jointly by three parties (Natural Resources Defense Council, Center for Biological Diversity, and Center for Marine Conservation, now known as the Ocean Conservancy). In response, NMFS issued a "90-day finding for a petition to list bocaccio (*Sebastes paucispinis*) as threatened" (66 Fed. Reg. 32304, June 14, 2001), and included a formal request for information. In response to that request, the NRDC submitted a letter[2] providing additional information regarding one of the factors thought to threaten bocaccio: the inadequacy of existing regulatory mechanisms.

The petition was based on the decline in bocaccio abundance reported in the 1999 stock assessment (MacCall et al. 1999), where the abundance in 1999 was estimated to be two percent of the abundance in 1969. The petition identified overutilization as the primary cause of this decline. Secondary issues raised by the petition were habitat modification (due to the effects of bottom trawling gear, pollution of nearshore juvenile habitat and shifts in oceanographic conditions) , and inadequacy of existing regulatory mechanisms (the latter issue was also addressed by the NRDC letter of 8/13/01). The petition asserts that listing of bocaccio would provide NMFS with stronger regulatory authority than presently exists with regard to both "take" and preservation of "critical habitat," and that NMFS would be obligated to prepare a detailed recovery plan.

BOCACCIO LIFE HISTORY AND ECOLOGY

Distribution and Habitat

Boccacio occur in coastal waters from Baja California, Mexico, to Alaska. The northern and southern segments of the population are separated by an area of scarcity off northern California and southern Oregon, a feature that is apparent from the record of Russian catches made during a period of high bocaccio abundance, 1963-1978 (Figure 1). Genetic analysis indicates that bocaccio from southern California and central California (Monterey) are a well-mixed population, but do not mix extensively with fish sampled from Washington waters (Russ Vetter, NMFS, SWFSC, personal communication). For purposes of fishery management, the Pacific Fishery Management Council (PFMC) treats the northern and southern segments of the population as separate management units, but treats bocaccio off southern and central California as a single management unit.

A portion of the bocaccio population resides in Mexican waters. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys of fish larvae extended into Mexican waters routinely until 1985 (Hewitt 1988, Moser et al. 2000). Data on bocaccio larval abundances (which are indicative of spawning adult abundances) are available for surveys conducted off California and Mexico from 1972 to 1985. During this period, Mexican waters accounted for about ten percent of the larval abundance, with the remainder split about evenly between southern and central California.

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[2] Andrew Wetzler and Drew Caputo, Natural Resources Defense Council, letter to Jim Lecky, NMFS, August 13, 2001.

Bocaccio do not show strong habitat specificity. Adults (both in schools and singly) are often found in association with rocky areas, from near-surface to depths exceeding 100 fathoms. Juvenile bocaccio (age three to six months) sometimes form dense schools in the nearshore area. Bocaccio are one of most mobile rockfish species, and are capable of moving freely throughout the range of the southern stock.

Life History

Bocaccio copulate in the late summer to early fall, and females bear their young live in the winter months. Offspring (larvae and early juveniles) are pelagic until early June, when they move toward the shore and settle to the bottom where they develop as juveniles. They grow rapidly, but typically take five years to mature. Based on the oldest fish that have been seen, bocaccio may live up to 30 or 40 years. The mean generation time (the average time required for offspring to replace the parents) is 12 years (Figure 2).

Bocaccio do not participate in any known interspecies relationships of special significance, magnitude or importance. They serve as prey to larger organisms, including marine mammals. Juvenile bocaccio can provide a significant component of seabird diets, but this is rare and only occurs approximately one month every decade. Bocaccio are predatory fish, and consume a wide variety of smaller fishes, including adults and juveniles of many species of rockfish including bocaccio.

Abundance and Reproduction

The most recent stock assessment (MacCall 2002) treats the bocaccio population off southern and central California as a single fully-mixed unit stock. The portion of the stock off Mexico is implicitly included in the assessed population. Treatment of the southern California and central California portions of the resource as separate assessment units was explored during the 2002 stock assessment, and some aspects of that exploration are used in this status review.

MacCall (2002) estimated historical abundance for the period 1951 to 2002 (Figure 3), whereas MacCall et al. (1999) were able to estimate abundance only for 1969 to 1999. Notably, the longer history shows that abundance fluctuated substantially before 1969, which was very near the historical peak. Thus the extent of decline from 1969 to 1999 exaggerates the depletion relative to a longer term baseline of abundance, e.g., relative to the 1951-1975 average abundance. Because bocaccio reproduction consists of rare large yearclasses, adult abundance is highly variable even in the absence of fishing.

Bocaccio recruitment (the young fish added to the population as the result of parental reproduction) is characterized by rare large events, and most of the population consists of fish from a very small number of years (Figure 4). The past 25 years has produced only three large recruitments (in 1977, 1984 and 1988). The 1999 and 2002 yearclasses appear to be large, but it is too soon to obtain a reliable quantitative estimate of their strengths. In contrast, the decade between 1969 and 1979 produced four large yearclasses. Long-term ocean climate patterns appear to have a strong influence on the frequency of large recruitments. Although this relationship cannot yet be quantified, the cooler ocean since 1998 is similar to the cool conditions of the 1960s and early 70s, and may be associated with better bocaccio reproduction. The protracted and extremely warm conditions of the 1990s was associated with poor reproduction of most rockfish species, including bocaccio, and undoubtedly contributed to the decline in abundance.

The historical relationship between estimated parental abundance and subsequent recruitment shows little or no evidence of increased reproductive rate at low abundances (Figure 5). The long-term average reproductive success only slightly exceeds the level needed to replace natural losses of parents (replacement), so that future abundances resemble the mathematical process of a “random walk” (a process characterized by lack of consistent trend and increasing variability over time).

A somewhat different pattern emerges when southern California is considered separately (MacCall 2002). The southern California segment shows much more productivity than the central California segment of the population, which is nearly neutral in net productivity (Figure 6). The combined stock assessment (MacCall 2002) is heavily influenced by the central California condition, and was favored by the Stock Assessment Review (STAR) Panel peer-review for purposes of fishery management. However, for purposes of evaluating the long-term existence of the resource, the viability of the portion of the stock in southern California may be an appropriate alternative measure of status.

HISTORICAL AND PRESENT STATUS OF FISHERY MANAGEMENT

Summary of MSFCMA Requirements

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) imposes regulatory requirements with regard to continuing existence of fishery resources that in many respects are more stringent than would be imposed by the ESA. The following summary highlights those MSFCMA aspects that relate to ESA considerations.

The National Standards established by the MSFCMA (16 U.S.C. 1851, § 301(a), “National Standards for Fishery Conservation and Management”) require, among other things, that:

> (1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery;
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> (3) To the extent practicable, an individual stock of fish shall be managed as a unit throughout

its range; and

(6) Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources and catches.

Fishery management under the MSFCMA requires development of fishery management plans (16 U.S.C. 1853, § 303(a), "Contents of Fishery Management Plans") with required provisions including:

(1)(A) measures necessary and appropriate for the conservation and management of the fishery to prevent overfishing and rebuild overfished stocks, and to protect, restore and promote the long-term health and stability of the fishery;

(3) assessment and specification of the present and probable future condition of, and the maximum sustainable yield and optimum yield from, the fishery;

(10) specific objectives and measurable criteria for identifying when the fishery to which the plan applies is overfished, and in the case of a fishery which the Council or the Secretary has determined is approaching an overfished condition or is overfished, the FMP must contain conservation and management measures to prevent overfishing or end overfishing and rebuild the fishery.

The MSFCMA imposes further requirements on management of fish stocks that have been identified as "overfished" (16 U.S.C. 1854, § 304(e), "Action by the Secretary"). The Council, through its fishery management plan must:

(3)(A) Within one year, prepare a fishery management plan, plan amendment, or proposed regulations to end overfishing and rebuild affected stocks;

(4) In its fishery management plan, amendment or proposed regulations, specify a time period for ending overfishing and rebuilding the fishery that shall be as short as possible and not exceed 10 years except where biology of the stock or other environmental conditions dictate otherwise.

Appropriate actions under the latter exception are described by the Magnuson-Stevens Act Provisions; National Standard Guidelines; Final Rule issued by NMFS in 1998 (50 CFR part 600). Regarding §600.310 National Standard 1 – Optimum Yield, (e) Ending overfishing and rebuilding overfished stocks, (4) Constraints on Council action, (ii) Council action must specify a time period for rebuilding the stock that satisfies the requirements of section 304(e)(4)(A) of the Magnuson-Stevens Act. This continues, (B)(3) If the lower limit [of the time period for rebuilding] is 10 years or greater, then the specified time period for rebuilding may be adjusted upward ... except that no such upward adjustment can exceed the rebuilding period calculated in the absence of fishing mortality, plus one mean generation time or equivalent period based on the species life-history characteristics. For example, suppose a stock could be rebuilt within 12 years in the absence of any fishing mortality, and has a mean generation time of 8 years. The rebuilding period, in this case, could be as long as 20 years.

Bocaccio has been identified as a species that cannot be rebuilt within 10 years (MacCall and He 2002), and is therefore subject to the above National Standards Guidelines requirement that the time period for rebuilding not exceed the length of time it would take in the absence of fishing (97 years), plus one generation time (12 years). This time period is assumed to begin in the year following designation of the stock as overfished, i.e., the first year of rebuilding is 2000.

History of Bocaccio Fishery Management

Until recently, fishing pressure on bocaccio has been higher than levels now believed to be optimal for rockfish exploitation (Figure 7). Until the mid-1990s, the resource was believed to be capable of withstanding an exploitation rate that is commonly applied in fisheries throughout the U.S. and worldwide, F35%[3]. This is a fishing rate that reduces the expected average lifetime reproductive output of a fish to 35% of the output it would achieve in an unfished condition (note that this criterion, called relative spawning potential, SPR, naturally scales the fishing rate to the life history properties of the species, see Clark 1991). In the late 1990s, the PFMC recognized that rockfish stocks were continuing to decline and concluded that this fishing intensity was too high for rockfish species. The PFMC subsequently modified the rockfish harvest policy to F40% in 1998 and again to F50% in 2001 (Ralston 2002). The current policy of F50% is an extraordinarily low rate of fishery exploitation by worldwide standards.

In 1999 the bocaccio resource was formally declared "overfished" in accordance with the newly-passed reauthorization of the MSFCMA, which had strengthened national policies intended to reduce and eliminate overfishing (see summary above). Following the declaration, a rebuilding analysis (MacCall 1999) was conducted based on the results of the1999 stock assessment (MacCall et al 1999), and the PFMC implemented a rebuilding policy beginning in 2000. Formal establishment of rebuilding policies as PFMC fishery management plan amendments has gone slowly, but all required regulatory actions associated with rebuilding have been implemented in a timely manner nonetheless. The bocaccio rebuilding policy initiated in 2000 established a rebuilding time of 37 years (calendar year 2037). The total target catch was to be held at a constant value of 100 metric tons (mt) for the years

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[3] Fishing rates can be expressed as catch/average biomass (instantaneous fishing rate, F) or as catch/initial biomass (exploitation rate, E). At low fishing rates (less than 10%) these two values are similar in magnitude. In either case, a target SPR level may be specified, such as F50% or E50%, in which case they are exactly equivalent.

2000 through 2002, and in 2003 the intent was to switch to a corresponding constant harvest rate that would set annual catches according to resource abundance. The target 100mt catch was exceeded in 2000 and 2001, as the PFMC is in the process of "learning" how to track within-year catches and to reduce harvests of a single species within a complicated mix of fishing modes and biological co-occurrences. Since 2000 the PFMC has implemented progressive restrictions not only on allowable catches of bocaccio, but on allowable catches of other species that tend to co-occur with bocaccio (e.g., chilipepper, *Sebastes goodei*), and also established closed seasons designed to reduce the overall level of fishing activity likely to encounter bocaccio. Recent exploitation rates have dropped substantially (Figure 7). In response to indications that the 2002 target catch is being achieved too early in the season, the PFMC enacted unprecedented gear, season and area fishing restrictions beginning in July, 2002 in order to minimize further catch of bocaccio.

The 2002 bocaccio assessment (MacCall 2002) and rebuilding analysis (MacCall and He 2002) were completed in June 2002. The new assessment provides an extended 50-year view of bocaccio fluctuations, and also incorporates an expanded set of resource observations from both southern and central California. Although the new assessment showed the relative depletion to be not quite as severe as previously thought, the estimated average rate of fish production was lower than in the previous assessment. Consequently, the new rebuilding analysis indicated that rebuilding would be slower and more erratic, requiring 98 years (from a start date of 1999, the year that the overfished status was formally declared) even in the absence of fishing.. The new rebuilding target date is 2172, and the rebuilding OY for 2003 is "as close to zero as possible, but not to exceed 20 mt."[4]

CONSIDERATION OF THE "SPECIES" QUESTION

Criteria for Identification of Distinct Population Segments

The joint policy of the US Fish and Wildlife Service (USFWS) and NMFS provides guidelines for defining distinct population segments (DPSs) below the taxonomic level of species (USFWS-NMFS, 1996):

Discreteness: The first of two elements to be considered is the discreteness of a population segment with respect to the rest of the populations within the species. Genetic differences between the population segments being considered may be used to evaluate discreteness. The policy also states that international boundaries within the geographical range of the species may be used to delimit a distinct population segment in the United States. This criterion is applicable if differences in the control of exploitation of the species, that management of the species' habitat, the conservation status of the

[4] October 2002 Draft Federal Register Announcement by NMFS, Magnuson-Stevens Act Provisions; Fisheries off West Coast States and in the Western Pacific; Pacific Coast Groundfish Fishery; Annual Specifications and Management Measures.

species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment in the United States.

Significance: The second element in defining distinct population segments is that the segment must be biologically or ecologically significant. Significance is evaluated in terms of the importance of the population segment to the overall welfare of the species. Some of the considerations that can be used to determine a discrete population segment's significance to the taxon as a whole include:

1) Persistence of the population segment in an unusual or unique ecological setting;

2) Evidence that loss of the population segment would result in a significant gap in the range of the taxon; and

3) Evidence that the population segment differs markedly from other populations of the species in its genetic characteristics.

Distinct Population Segments of Bocaccio

Northern vs. Southern Stock: The northern and southern bocaccio stocks meet both the discreteness and significance criteria for treatment as separate DPSs. Genetic differences (ca.. 10% probability of obtaining the observed differences if the two populations are not separate) have been identified (Vetter, NMFS, SWFSC, Pers. Comm.), and there is a gap in the geographic distribution in the area of northern California and southern Oregon (Figure 1). The remainder of this review will address only the southern stock as a DPS, that population segment having been the subject of the listing petition that generated this biological review.

Southern California vs. Central California: Genetic similarity of bocaccio from southern California and central California indicates that these two segments are not isolated. The southern and central California segments of the southern bocaccio stock have been combined for fishery assessment and management purposes under the Pacific Fishery Management Council. The primary implication is that catches taken from either segment are considered to have an equivalent impact on the stock. As a gap in bocaccio abundance already exists north of central California (Figure 1), hypothetical loss of bocaccio in central California would only widen a geographic gap between the two DPSs that already exists. Based on the sequence of anecdotal reports from southern and central California fishermen, both the strong 1999 and 2002 yearclasses appeared to "spill over" from southern California into central California as juveniles, indicating that the central California segment is easily repopulated from southern California. Thus there is no reason to treat southern and central California segments of the bocaccio stock as DPSs, or as otherwise significant geographic areas for purposes of the ESA.

Transboundary and International Issues: The southern bocaccio stock extends into Mexican waters. The current Mexican portion of the total stock abundance is not known, but historical (1972-1985) larval abundances indicate a value of about ten percent. Bocaccio larval abundances declined at all locations during the 1972 to 1985 period, and the relative decline in Mexican waters was similar to that in U.S. waters. Due to the relative inaccessibility of northern Baja California waters to fishermen, historical fishing pressure on bocaccio has probably been lighter than in U.S. waters, and the current portion of the bocaccio stock residing in Mexican waters may be somewhat above ten percent, but is probably not large. Although it can be argued that regulatory mechanisms differ between the U.S. and Mexico and that bocaccio catches in Mexico would potentially influence the conservation status of bocaccio in the U.S. to some degree (the discreteness criterion), that influence is presumably small given the relative sizes of the stock segments. Treatment of the Mexican segment of the bocaccio stock as a separate DPS is not warranted.

In conclusion, the DPS treated in this review consists of the bocaccio off California and Mexico (extending to approximately 200 miles south of the U.S.-Mexican border). The portion in Mexican waters is approximately ten percent of the total southern stock DPS.

CONSIDERATION OF THE "EXTINCTION RISK" QUESTION

Evaluation of Risk Factors

As listed in the Introduction, a number of factors must be considered in evaluating the status of the petitioned species.

Absolute numbers: Absolute numbers of bocaccio in the southern stock is 1.6 million fish (age 1 and older) in 2002 (MacCall 2002). About 1.0 million of these fish are south of Pt Conception, where recent recruitments have been relatively stronger. Fish are older and average size is larger north of Pt. Conception. Absolute numbers corresponding to "extinction" is not known, but current abundance is far higher than conventional "extinction" values (usually hundreds or thousands of individuals) used for other species.

Relative abundance: Current abundance (2002) of the southern stock is 3000 mt, with 1300 mt occurring south of Pt. Conception (MacCall 2002). Current reproductive potential is 720 billion eggs (243 billion eggs south of Pt. Conception). Estimated unfished reproductive potential of the southern stock is 19849 billion eggs, with a CV of 31% (MacCall and He 2002). The current reproductive potential is 3.6% of the estimated average unfished level, and is low by conventional fishery management standards (e.g., 40% of the unfished abundance is often considered to be healthy, and in the specific case of bocaccio, this is the Pacific Fishery Management Council's rebuilding target).

Trends in abundance: Abundance can be measured as spawning potential, which is the quantity of spawning products that the population is capable of producing. This measure accounts for both numerical abundance and effects of age structure and maturation schedules where older individuals are disproportionally more fecund. Historical abundance, measured as spawning potential, has been estimated since 1951 (MacCall 2002). Between 1951 and 1969, abundance fluctuated between 26%

(in 1960-61) and 95% (1969) of the estimated average unfished level (Figure 3), demonstrating the natural tendency of bocaccio abundance to fluctuate strongly over time. After 1969, relative abundance declined steadily to its current relative value of 3.6% of estimated unfished abundance.

Natural and human-influenced factors that cause variability in survival and abundance: Environmental conditions providing for successful reproduction (i.e., producing more offspring than are needed to replace the current year's natural losses) are not understood, but such events are infrequent, and have occurred in 13 of the last 50 years (26%), and only 4 of those events were large enough to replace more than the average 3.8 years (1/0.26) between successful reproductions. Importantly, none of those unusually large events have happened since 1978, contributing to the decline in abundance. The U.S. west coast experiences a 60-year cycle of conditions that alternate between favorable (ca. 1941 to 1975) and unfavorable (1976 to 1998) for many coastal species of fish (MacCall 1996). It is likely that the higher frequency of poor bocaccio reproductive successes since 1978 (and especially during the 1990's) has been associated with the unfavorable phase of the long-term ocean climate cycle. Evidence is accumulating that a new favorable period began in 1999, and bocaccio have recently achieved two successful reproductions, in 1999 and in 2002. This also demonstrates that the stock has not been reduced to a "depensatory" level where reproductive rate decreases due to such phenomena as inability to find mates.

The primary cause of the current low abundance is excessive harvesting, particularly during the 1980s and early 1990s when the stock was believed to be capable of sustaining an F35% harvest rate. Recent bocaccio management associated with the MSFCMA requirement for ending overfishing and rebuilding the stock has reduced fishing pressure to levels conducive to long-term population growth. The risk of further bocaccio decline under a rebuilding program is evaluated quantitatively in the following section on Population Viability Analysis.

Both natural conditions and fishery management policy now provide for a much more optimistic outlook than was the case during the most of the bocaccio decline. The ocean climate cycle appears to be in a more favorable phase for bocaccio reproduction, and fishery management has formally embraced stock rebuilding policies. Because of these changes, the most important natural and human factors associated with the historical decline in bocaccio are no longer operative.

Threats to genetic integrity: There are no known threats to the genetic integrity of bocaccio.

Recent events: The most important recent events that influence the status of bocaccio are the apparent shift to a more favorable ocean climate beginning in 1999, and the strengthening of the MSFCMA with regard to rebuilding overfished stocks.

Additional risk factors: The optimistic outlook for fishery management is based on the PFMC's continuing adherence to the rebuilding requirements specified in the MSFCMA. However, if the bocaccio rebuilding program is weakened or abandoned (for example, if the PFMC invokes the "mixed stock exception"[5] to allow increased harvest of bocaccio), the risk of further decline in the species will be higher, and the following Population Viability Analysis would require revision.

Population Viability Analysis (PVA)

The PFMC's rebuilding policy is designed to achieve population growth over the long term, but the irregular recruitment pattern exhibited by bocaccio results in a risk of further decline (especially in the first few decades) despite the rebuilding policy. The bocaccio rebuilding analyses provided to the PFMC (MacCall and He 2002) utilized the standard rebuilding software package developed by Andre Punt of the PFMC's Scientific and Statistical Committee (SSC). Here, the SSC rebuilding software was also used to investigate the risk of further decline in bocaccio abundance under alternative fishery management scenarios. The simulation involves simulating the next 100 years of bocaccio abundance by random resampling of recruitment successes (recruits per spawner) from the historical series 1953 to 1999, which are treated as equally likely values of what will happen in the future. Table 1 presents alternative constant fishing rates considered by the PFMC; the fishing rates are given, but are also associated with what the catch would be in 2003, and what the probability of no further decline is in the next 100 years. Specifically, the PFMC has proposed a rebuilding policy such that the OY for 2003 that "is as small as possible, not to exceed 20 mt, roughly corresponding to fishing rate with an 80% probability of no further decline in abundance over the next 100 years. A total of 10,000 simulations were run for each case in order to achieve good precision despite the underlying recruitment variability. Abundances at the end of 25 and 100 years are expressed as spawning outputs (billion eggs) or as spawning output relative to the present estimate of 720 billion eggs. The median value (50 percentile) is given as a likely result of long-term fishing at the given rate. Risk is expressed as the lowest 5 percentile of abundance, a fairly unlikely outcome, but useful as a "worst-case" scenario. The 5 percentile abundances are reported for 25 years and 100 years in the future (calendar years 2027 and 2102).

Abundance levels corresponding to "extinction" have not been defined in this PVA, as no exploited marine fish is known to have gone extinct–there is no precedent on which to base such a value. The lowest 5 percentile abundance given in the tables is 1.9% of the present abundance, which is roughly equivalent to 57 mt, or 30,000 individual fish.

[5] The Magnuson-Stevens Act Provisions; National Standard Guidelines; Final Rule issued by NMFS in 1998 (50 CFR part 600). Regarding §600.310 National Standard 1 – Optimum Yield, (d) Overfishing, (6) Exceptions. There are certain limited exceptions to the requirement to prevent overfishing. Harvesting one species of a mixed-stock complex at its optimum level may result in the overfishing of another stock component in the complex. A Council may decide to permit this type of overfishing only if all of the following conditions are satisfied: ... (iii) The resulting rate or level of fishing mortality will not cause any species or evolutionarily significant unit thereof to require protection under the ESA.

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Table 1. Population Viability Analysis for the combined southern and central California bocaccio stock. The Pacific Fishery Management Council's proposed rebuilding plan corresponds most closely to the line in bold.

					Risk (five percentile of abundance)			
Probability (%) of no decline by 2102	Catch in 2003	Fishing Mortality Rate	Percent of cases rebuilt by 2109	Median Rebuilding Year	after 25 years		after 100 years	
					Spawning Output (billion eggs)	2027 Abundance Relative to 2002	Spawning Output (billion eggs)	2102 Abundance Relative to 2002
50%	79	0.094	7%	14% by 2602	73.1	10%	2.5	0%
60%	61	0.071	12%	31% by 2602	85.8	12%	5.5	1%
70%	42	0.049	21%	50% by 2367	102.6	14%	13.3	2%
80%	**22**	**0.026**	**33%**	**50% by 2172**	**126.1**	**18%**	**30.7**	**4%**
85%	11	0.012	41%	50% by 2135	145.2	20%	52.7	7%
90%	0	0.000	49%	50% by 2111	157.5	22%	86.3	12%

Figure 1. Catch locations of bocaccio in the Russian fishery.

Figure 2. Net maternity function (product of survivorship and fecundity) for bocaccio, normalized to unit area.
Mean generation time is 12 yr.

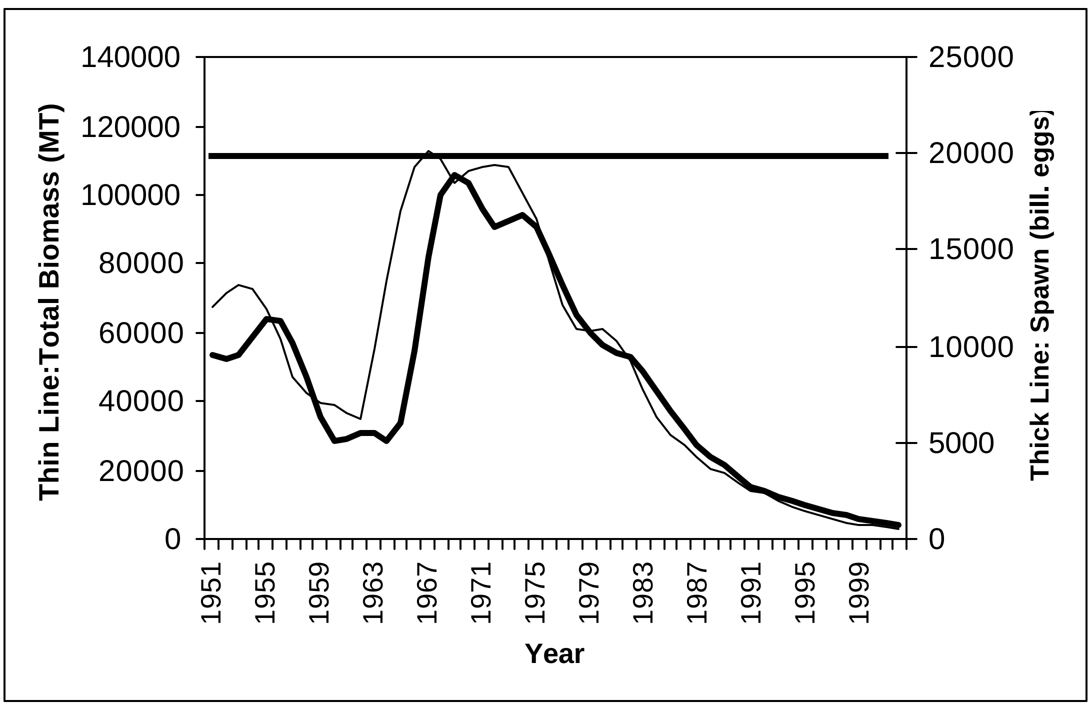

Figure 3. Estimated historical bocaccio abundances. Horizontal line is estimated unfished spawning output (19849 billion eggs).

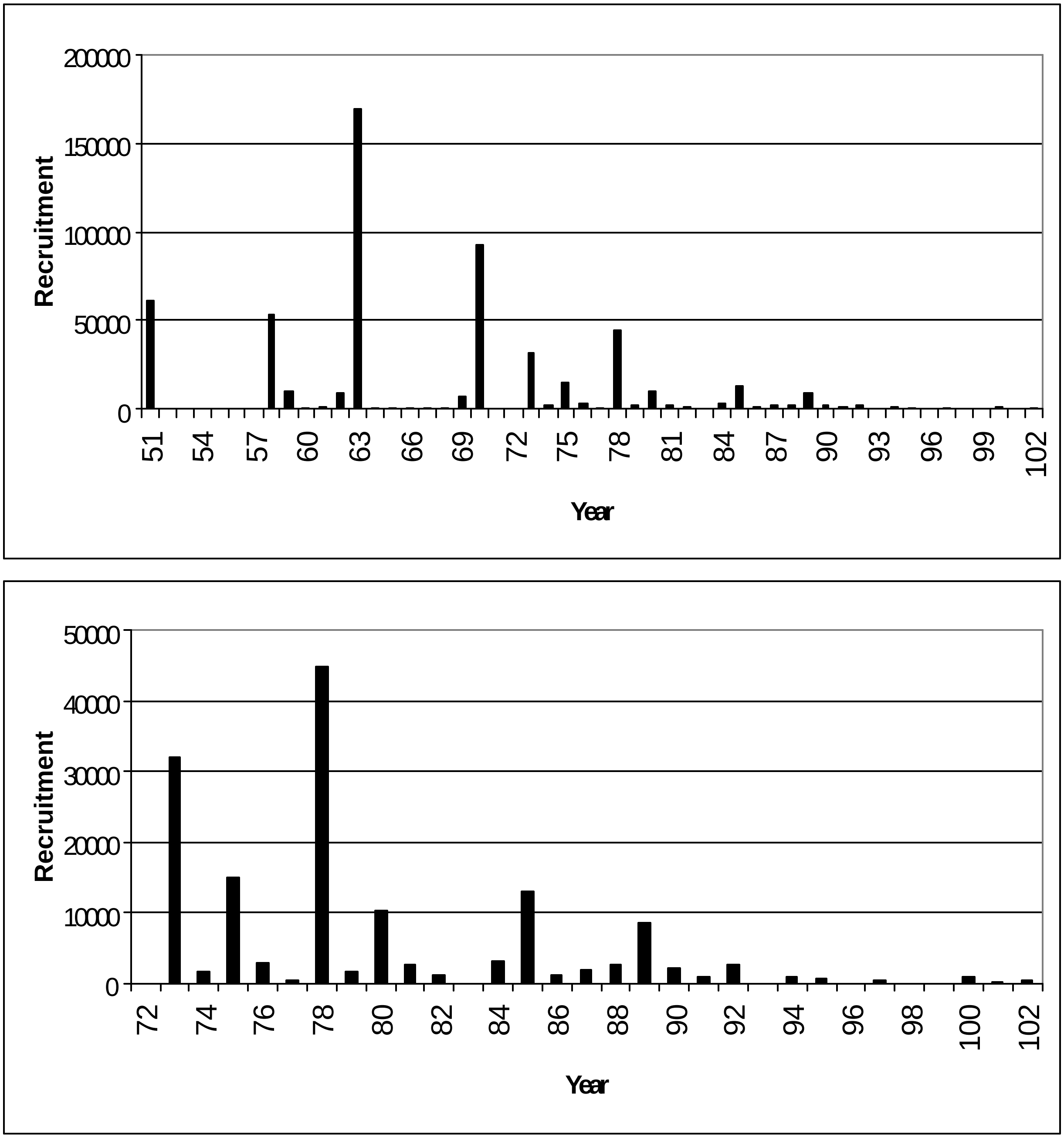

Figure 4. Estimated bocaccio recruitment strengths. Lower panel shows detail of recent years.

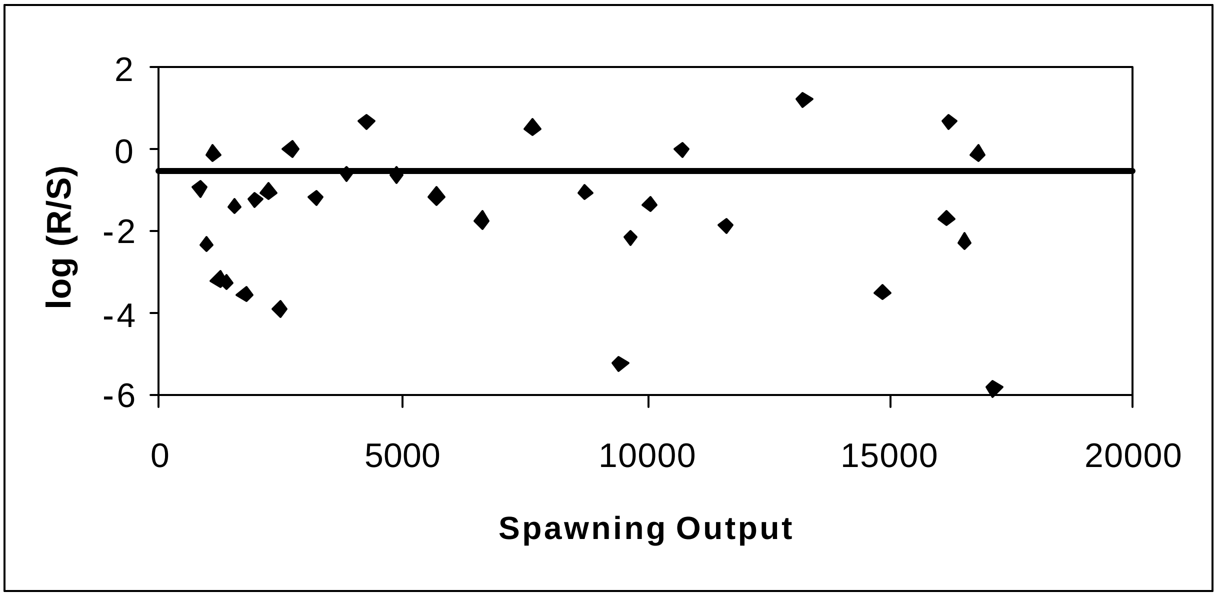

Figure 5. Historical reproductive success related to parental abundance. Horizontal line is replacement level in the absence of fishing. Points represent individual historical years.

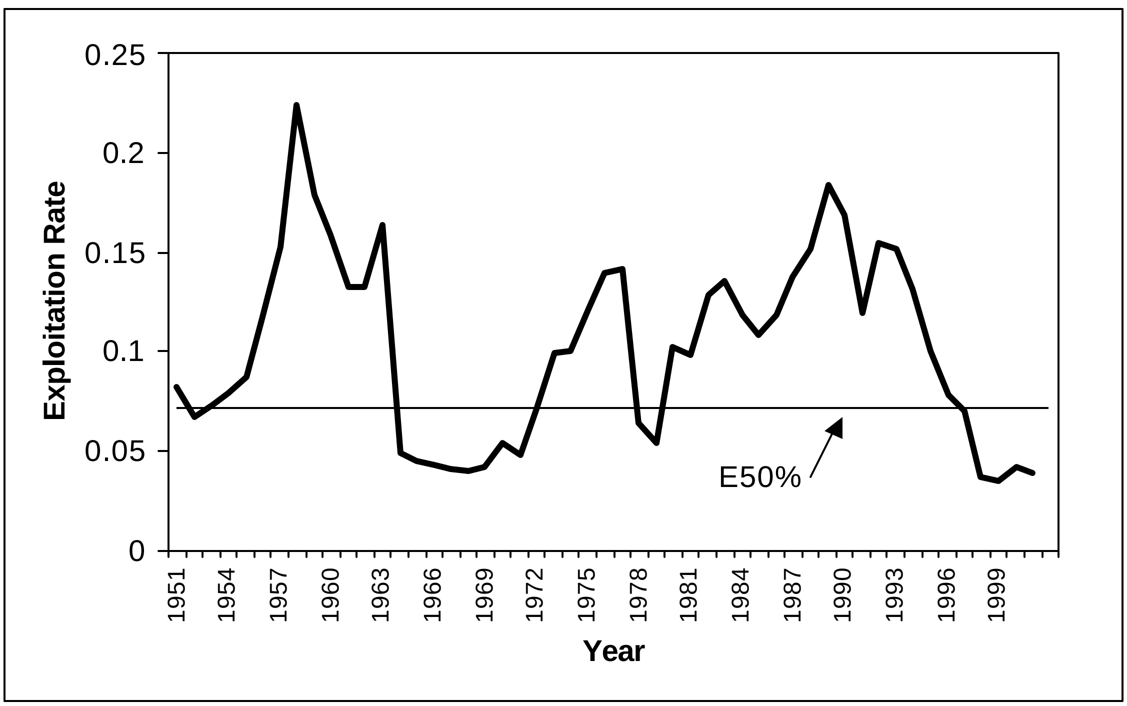

Figure 6. History of bocaccio exploitation rates (catch as fraction of age 2+ biomass). Horizontal line is exploitation rate corresponding to fishing intensity at maximum sustainable yield.